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RESEARCH NOTE

CENTRAL STATES FOREST EXPERIMENT STATION
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ARTIFICIAL DEFOLIATION OF EASTERN WHITE PINE DUPLICATES SOME EFFECTS OF CHLOROTIC DWARF DISEASE

Chlorotic dwarf is reported from all over the normal range of eastern white pine (Pinus strobus L.). The disease reduces the growth and prematurely defoliates this pine. It affects 3-year-old trees, those as old as 15 years, and, rarely, even trees as old as 40 years. Though it has been known for 50 years, its cause is still unknown.

An attempt to duplicate some chlorotic dwarf symptoms by artificially defoliating healthy white pines indicates that premature shedding may be responsible for the reduced growth that is customarily associated with the disease. Removal of current needles is more likely to slow the growth of shoots and even kill healthy trees outright than removal of older foliage.

Normally eastern white pine holds 3 years' needles during the summer months. After the oldest needles are sloughed off in autumn, current and 1-year-old needles overwinter. New needles emerge in the spring and the cycle continues. But trees afflicted with the chlorotic dwarf disease deviate from the norm. Their failure to retain needles is one of the most characteristic symptoms of this disease. In all stages of tree decline, chlorotic-flecked foliage formed the preceding year falls prematurely by early summer, leaving only the new needles. Few of the trees with chlorotic dwarf disease die in young plantations, only 4 of 250 diseased trees being lost over a 4-year period of observation. But more of these disease-stunted trees may die in time because of suppression by surrounding healthy trees.

Methods

Artificial defoliation was studied in a 5-year-old white pine plantation at the Memorial and Mohican State Forests in Ohio in 1960 and 1961. Sixty healthy white pines were randomly selected from trees growing on similar sites. Four different treatments were compared: complete defoliation, removal of current needles only (those that grew out in 1960), removal of all foliage except current needles, and no defoliation. One-third of the 60 trees were treated in July 1960 during the growing season, one-third in late September 1960 during the dormant season, and one-third in April 1961 before candle elongation. Five trees received a particular treatment each time.

Growth in 1960 was compared with growth in 1961, height of each tree and annual growth of four of its shoots being measured. Both tree height and shoot growth were analyzed statistically to establish significance of response to all treatments. Radial growth was not measured because it is difficult to accurately record in young trees. Vigor and survival were taken into account in final records.

Results

In some cases all five of a group of treated pines died and it was not possible to compare growth before and after defoliation. But number of defoliated pines killed gave some idea of importance of the particular needles removed and the effect of time of defoliation. Complete defoliation killed all five trees so treated in July and all five so treated in April. But it killed only three white pines out of the five so treated in September. When carried out in April, removal of current needles also killed trees, only one white pine out of five treated at that time surviving. But when current needles were removed in July and September, all trees survived. When current needles were retained but all others removed, all trees survived, regardless of season of defoliation.

Growth and vigor of trees surviving were more influenced by age of needles removed than by season of defoliation. The two trees that survived complete defoliation displayed chlorotic dwarf-like symptoms of shortened internodes and chlorotic needles (figs. 1 and 2). Their shoot growth was greatly reduced (table 1).

FIGURE 1 (Right).--A healthy eastern white pine completely defoliated in September 1960 showed chlorotic dwarf symptoms the following year.

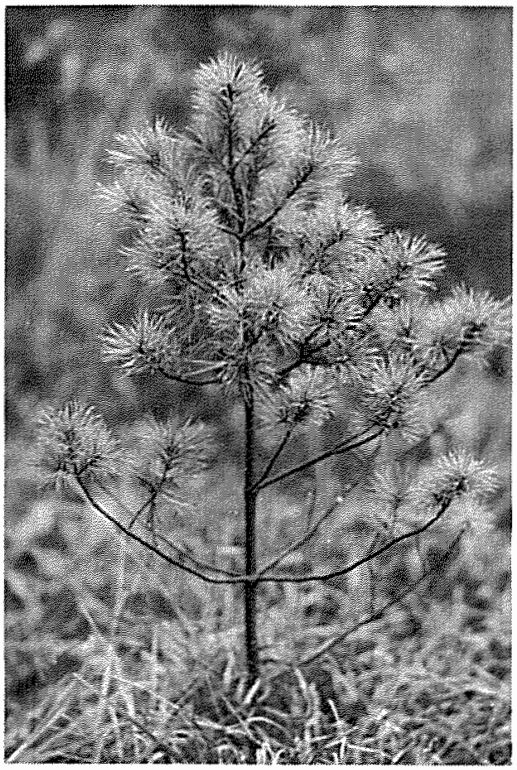

FIGURE 2 (Left).--Chlorotic dwarf symptoms in eastern white pine include premature defoliation, decreased growth, and short needles.

FIGURE 3 (Right).--Comparison of root systems of two 10-year-old chlorotic dwarf trees. The one on the left was terminally grafted with a healthy scion when 6 years old and now shows a much improved root system compared to the check tree.

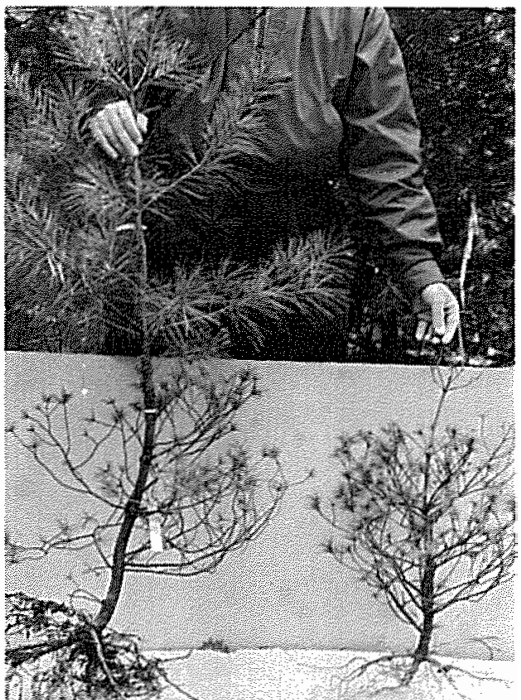

Table 1.--Shoot growth of eastern white pine during the growing season preceding artificial defoliation and during the growing season following defoliation[1/]

(In centimeters)

Treatment	Time of treatment					
	July 1960		September 1960		April 1961	
	Before	After	Before	After	Before	After
Complete defoliation	15.8	[2/]0.0	12.2	[3/]5.5	16.2	[2/]0.0
Removal of current (1960) needles only	14.1	6.4	14.4	7.8	16.2	[4/]4.8
Removal of all but current needles	14.6	19.6	14.8	21.6	16.4	21.1
No defoliation	15.9	22.1	15.1	22.8	17.2	23.5

1/ Evidence indicates that annual growth in white pine is completed by July (McGregor, W. H. D., and Kramer, P. J. Seasonal trends in rates of photosynthesis and respiration of loblolly pine and white pine seedlings. Amer. Jour. Bot. 50: 760-765. 1963). Measurements of shoot growth for each year were thus comparable even though time of treatment differed.

2/ No surviving pines.

3/ Two surviving pines.

4/ One surviving pine.

Table 2.--Height of eastern white pine before artificial defoliation and at the end of the first growing season after defoliation [1/]

(In centimeters)

Treatment	Time of treatment					
	July 1960		September 1960		April 1961	
	Before	After	Before	After	Before	After
Complete defoliation	81.0	[2/]0.0	41.0	[3/]50.5	78.6	[2/]0.0
Removal of current (1960) needles only	73.6	79.0	67.0	77.6	68.0	[4/]75.0
Removal of all but current needles	86.6	128.8	72.4	111.4	77.0	96.0
No defoliation	81.2	126.8	76.6	120.8	85.6	133.1

1/ Growth in height in 1960 is included in "before" figures; that in 1961 in "after" figures. "Before" figures are comparable to each other as are "after" figures (see footnote 1, table 1).

2/ No surviving pines.

3/ Two surviving pines.

4/ One surviving pine.

When only current needles were removed, needle chlorosis and shortening were less pronounced. Though removal in July and September reduced shoot growth, effects were most severe in the single tree surviving April treatment. Growth of its shoots was reduced as much as that of the two trees surviving complete defoliation. Presumably old needles were less effective in photosynthesis when current needles were removed in April than when removed earlier.

Stripping all needles except current ones did not cause any visible disease symptoms and did not affect growth in height (table 2). Thus, in contrast to current needles, old needles apparently contribute little to overall growth and survival.

Discussion

Eastern white pine has been artificially defoliated in another investigation.[1/] Other species that have been so treated include jack pine (P. banksiana Lamb.),[2/] jack pine and Scotch pine (P. sylvestris L.),[3/] and tamarack (Larix laricina (Du Roi) K. Koch.[4/] Results obtained agree with findings of this study. That is, complete defoliation is usually fatal and needles of the current year are more important for shoot growth than older needles.

Decreased shoot growth and stunted needles that are produced by artificial defoliation resemble symptoms displayed by diseased trees. This suggests that many of the later manifestations of the chlorotic dwarf disease result from the premature defoliation. This supposition is supported by findings that indicate that chlorotic dwarf symptoms on white pine roots are affected by the condition and amount of foliage.[5/] In 1959, healthy white pine scions were grafted to terminals

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1/ Linzon, S. N. The effects of artificial defoliation of various ages of leaves upon white pine growth. Forestry Chron. 34: 50-56. 1958.

2/ O'Neil, L. C. Some effects of artificial defoliation on the growth of jack pine. Canad. Jour. Bot. 40: 273-280. 1962.

3/ Craighead, F. C. Some effects of artificial defoliation on pine and larch. Jour. Forestry 38: 885-888. 1940.

4/ Graham, S. A. The effects of defoliation on tamarack. Jour. Forestry 29: 199-206. 1931.

5/ Report to be submitted to Phytopathology.

of several diseased 6-year-old trees. After 3 years' further growth, crowns produced on these trees by the healthy scions are larger than crowns on all-diseased 9-year-old trees. Root systems have become vigorous and healthy even though they were originally small and unthrifty. Roots of the all-diseased 9-year-old trees are still in poor condition. This recovery of the root systems of grafted trees, unaccompanied by recovery of the diseased portion of tops, further suggests that it is loss of foliage that causes the other symptoms (fig. 3).

Conclusions

Premature defoliation is one of the most characteristic symptoms of chlorotic dwarf of eastern white pine. The needles formed the previous year are prematurely shed during the growing season, leaving only the newly produced chlorotic-stunted foliage. Although the cause of this malady remains unknown, this experiment shows that artificial defoliation of healthy young white pines can cause symptoms similar to those displayed by chlorotic dwarf trees and current foliage is more important to shoot growth than old foliage.

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